1.—Topical chemistry in Perth's air

Presidential Address, 1975

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Introduction

Last year Dr. Trendall's Presidential Address dealt with the banded iron formations in the northwest of this State and their genesis associated with the change in the composition of the Earth's atmosphere perhaps 2 000 million years ago. I shall be discussing some quite recent atmospheric chemistry again particularly relevant to Western Australia and the metropolitan area.

At any one average moment over the State of Western Australia there is present 300 million, million tons of air (that is over 10,000 times the mass of our known iron ore reserves), carrying water equivalent to at least 10,000 times the annual consumption in the metropolitan area and "traces" of carbon dioxide enough to make a cubical block of wood two miles each edge. It is a big subject. By natural meteorological processes involving prodigious amounts of potentially useable solar energy and wind energy the lower atmosphere is generally changing, air arriving from the southwest for example, whilst the current air progresses generally eastward. We humans use it as a source of oxygen rejecting carbon dioxide to it, plants do the converse by day, and of course it is a rubbish disposal service for factory emissions and traffic exhausts. Though neither import duties nor export controls are imposed on its movement by the Federal Government, air is an important and precious commodity.

No previous President however has elected to talk about the Atmosphere, indeed, even in the Society's extensive publications going back to 1914 (and its antecedents to 1897) only a few papers touch the topic. The air's inland transportation of agriculturally significant chemicals *is* treated in the Royal Society's Report on 'Salinity in Rain in Western Australia' (Professor Wilsmore Chairman 1928) and in Professor Drover's 'Accessions of Sulphur' (1960). Would modern replications of the latter be higher? Dr. Speck reported in 1953 on 'Atmospheric Pollen in the City of Perth and Environs'. And four papers indirectly relate to massive combustion in air: Miss Baird's 'Regeneration on Garden Island after fire' (1958), Dr. Hatch's Burning of the jarrah' (1959), 'Man the destroyer', Dr. Merrilees' Presidential Address (1967), and 'Fire in the jarrah environment', Dr. Wallace's Presidential Address (1966).

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Perhaps our oblique interest is because our city has never experienced pollution incidents such as the London pea-soup fogs (now almost eliminated by smokeless zone legislation) in which sulphur dioxide and smoke particles *jointly* disrupted the health and amenities of European industrial cities.

Be that as it may be, no professional chemist need apologise for discussing Air. No precise point can be given for the evolution of modern chemistry (just possibly Dalton's atomic theory 1807), but my biased choice as a gas experimentalist would be fellow Yorkshireman Joseph Priestley's characterisation and recognition of oxygen as a separate chemical species. Priestley knew about many of the gases I shall refer to later. Oxygen he prepared by the famous burning glass experiment. Solar energy again! Nitrogen he obtained by removing oxygen from air by combustion and by respiration (of mice and men). Nitric oxide he synthesised from the action of many metals on nitric acid. Most importantly for us, he knew that nitric oxide combined with oxygen to give the red water-soluble nitrogen dioxide, indeed this was Priestley's standard quantitative test for the 'goodness' of air, viz, its oxygen content. All firmly established by the 'pneumatic chemists' by 1775.

The compounds NO and NO_2 (quite distinct from N_2O-'laughing-gas') occur in barely measurable amounts, say a fraction of one part per hundred million in rural, uncontaminated air. Significant amounts are released during combustion of coal, of oil, of natural gas, etc., in furnaces and of petrol in the car engine, therefore both are found above natural levels in city, contaminated atmospheres. Neither is medically harmful at the levels I shall be speaking of tonight but they *are* centrally involved in photochemical smog.

Photochemical reactions

Controlled photochemical reactions in gases were first demonstrated a century ago by John Tyndall (1868) physicist, master experimentalist in bacteriology (he observed the inhibition of microbial growth by *Penicillium* fifty years before Fleming), noted science expositor, and a glaciologist who attempted to conquer the Matterhorn just before Whymper's tragic assault.

Air containing a trace of amyl nitrite vapour on illumination with sunlight, though intially optically clear, develops a brilliant fog as the energy of the light beam converts the amyl nitrite to a non-volatile material. The colours

of Tyndall's fogs, pink and green in this replication, failed to attract adequate investigation: similarly coloured monodisperse sols were rediscovered by La Mer (1941) and are explicable with light scattering theories due to Lord Rayleigh.

Many commentators for instance F. W. Went (1966) noted plant physiologist, have suggested that the ethereal atmospheric effects over, for example, Australia's Blue Mountains might have their origin in extremely fine particulates formed by the *natural* photochemical process of intense sunlight acting on organic vapours emitted by trees. Perhaps some of Gruner's paintings depict the phenomenon.

Let me move now to an *artificial* photochemical experiment on a massive scale. A detailed chemical exposition would be out of place here, I merely remind you of the essential features of photochemical smog formation in air contaminated with automotive emissions. Energy from sunlight otherwise passing harmlessly to ground is intercepted by the NO_2 molecule which then sets in train chemical degradation of hydrocarbons from uncombusted petrol. The chemical sequence is such that the NO_2 molecule is regenerated and continues its cyclic, catalytic role. In stagnant air the photochemical process results in a marked and characteristic loss of visibility, the formation of eye irritating chemicals, and enhanced ozone levels. Well documented social, economic and medical disabilities follow severe and repeated exposure to such conditions. For example, in the Los Angeles basin photochemical smog of man-made origin has severely or at least moderately damaged over 100,000 acres of the San Bernadino National Forest. Restoration of the pre-car era air quality has so far defeated all attempts.

Perth air: background information

One of the great delights of Perth has been its brilliant atmospheric clarity—a tourist attraction too! In the mid sixties, fresh from eighteen months in Los Angeles, I began to have qualms of chemical conscience, qualms engendered on clear winter mornings by perceptible odours reminiscent of Los Angeles, recognisable by myself and several others with personal experience of L.A. photochemical smog. (Incidentally, only life-long non-smokers should serve on air-control bodies.) Is there, I mused, the slightest possibility that photochemical processes within the emissions from our expanding road traffic, perhaps compounded by natural terpenes from eucalyptus, might lead at some distant future time to an occasional L.A. type incident? Almost everyone dismissed this as fantasy in 'the windiest capital city in Australia'. What could I do with very limited facilities which mght partially resolve this question? A remark of Charles Darwin helped: 'Once a week do a damn fool experiment, they hardly ever work but when they do they're marvellous'. Chemical analysis for ozone, hydrocarbons, 'oxidant', all indeed pose severe chemical and instrumental problems (i.e. financial problems) at the very low concentrations of interest to air chemists. The determination of NO and NO_2 together, colloquially NO_x, was a practical possibility which might be squeezed in alongside my mainstream research. The principal results are reported with detailed discussion in the Journal of the Royal Society (Bottomley and Cattell, 1975). Let me tonight emphasise the salient points, provide some illustrations, and add perhaps a little human interest.

Of about two hundred NO_x values measured at the University between June 1970 and June 1971 all the concentrations except two are inconsequential by world city standards. More interest arises when we note that most high NO_x values coincide with impaired atmospheric clarity of a special type. April 29th 1971 is particularly interesting. The NO_x value taken 8.00 a.m. to 10.00 a.m., following the morning traffic peak, was the highest recorded in that series, and is followed by a marked fall during the 10.00 a.m. to noon period just as the atmospheric clarity improves. This is simply a chemical verification that car (and other emissions) linger near the ground in stagnant late-autumnal morning air.

Unauthorised release of this comparatively high value (23.6 pphm) unleashed in the media an obscuring controversy about Perth's air. Criticism was made that the University site was quite unrepresentative of the Metropolitan area (though 10 000 of us have to breathe its air) and that Chemistry's oil-fired boiler was the cause: no critic asked if the boiler was working that morning. Thus Peppermint Grove became the site for further studies of truly suburban air.

Long-term studies

Photochemical sequelae would be more likely if car emissions remained relatively unmixed throughout a full morning of intense sunshine: I resolved then upon a year long examination, for just such persistence, in the air at home between 10.00 a.m. and noon. The year's results are really a chemist's view of the fluctuating meteorology of that year. Examination of the maximum value (10.00 a.m. to noon) obtained in every month locates April, May, June and July to be when inadequate morning mixing occurs. Peppermint Grove experienced some ten incidents in a year comparable to the April 29th, 1971, event at the University. If data had been collected 8.00 a.m. to 10.00 a.m. (not two hours later) I believe we would have exceeded the 23.6 pphm figure.

The main meteorological cause of the inability of the air to disperse car fumes is the existence of a shallow and intense inversion layer, the air temperature rising with height above ground instead of decreasing as normal. Dispersion of contaminants is delayed until the sun rises high enough to destroy or 'break-up' the inversion, when sudden mixing and therefore clearing occurs. The data for 1962 shows how common these inversions can be in Perth (Mackey 1963). The chemical data confirm these shallow inversions as an extremely important feature of Perth's meteorology in relation to car and other low-level emissions.

Let me offer just one statistical argument which directs the blame for the NO_x levels

towards cars. Day by day the values fluctuate remarkably because of Perth's variable weather, but if you virtually eliminate that factor by averaging the results for every Monday, every Tuesday etc., then this Table is obtained (over 55 weeks):

Mon.	Tues.	Weds.	Thurs.	Frid.	Sat.	Sun.
1·28	1·22	1·32	1·64	1·79 Highest	1·37	1·07 Lowest

which surely reflects our car habits. Very simple, very convincing!

The scope of these studies was greatly enlarged hereabouts by parallel work at Caporn Street Nedlands, carried out by Dr. Frank Cattell as the Western Mining Corporation Fellow at the University of Western Australia in 1972 and 1973. Clear evidence was produced that Peppermint Grove and Nedlands experience somewhat similar effects from traffic emissions and that NO predominates in the ambient NO_x mixture. The daily data for both sites has been smoothed to reduce the effects of short term weather fluctuations by taking a thirty day moving average: it confirms again that the early winter period is of greatest concern. Furthermore when the NO_x on a daily basis is high at Peppermint Grove, it is high also at Nedlands. These highs are *not* from local sources like Chemistry's boiler acting in an uncoordinated way, very likely other parts of the Metropolitan area are similarly affected.

So far I have been concerned with morning traffic: what about the evening exhaust fumes? Mid April 1972 provided some novel and disconcerting information. The Bureau of Meteorology issued an air dispersion alert on April 14th, 1972, for the Friday evening to Saturday noon. The University wind records showed a forty hour calm starting 6.00 p.m. Friday the 14th. Thus alerted we instituted some special studies. We believe the massive late evening peaks to be due to the evening traffic emissions drifting very slowly westward from the city whilst held at high concentration in a very shallow layer by radiation inversions.

Perth weekday traffic covers at least a million car-miles between 3.00 p.m. and 8.00 p.m. At the then current Californian standard of 4 grams of NO per mile, this human mobility releases 3 tonnes of NO_x. If that is dispersed into a cylinder of air ten kilometres diameter and 100 metres deep (a rough guess for the affected air space) then the average concentration is 20 pphm.

The higher values in the evening peaks surely provoke speculation about other car emission chemicals. As a rough and ready rule overseas experience is that carbon monoxide levels are 40 times the NO_x: if so for our Perth suburbs, on these special occasions the United States air quality standards for carbon monoxide (not to be exceeded more than once a year) were violated on at least four evenings.

Photochemical events and ozone formation

Should the incidents detected in the evenings persist until well into the sunlit morning, perhaps with additional NO_x gained from the morning traffic emissions, then photochemical cons quences would certainly occur. Possibly the April 29th, 1971, morning peak was indeed one such incident.

Dr. Cattell made some preliminary assessment of 'oxidant' (a photochemical component) by the buffered potassium iodide method and by the ethylene chemiluminescent reaction method which is specific for ozone. A study was made of how NO,NO_2 and ozone levels varied during one winter's day, the time sequence is typical of photochemical reactivity. Ozone concentrations on one of three summer days in November-December 1972 (part of a short series studied) reached levels which American authorities would regard as indicative of mild photochemical smog.

I mention-caveat-that 1972 was an unusual year weatherwise: ten air dispersion alerts were issued by the Bureau of Meteorology, compared to 2 in 1973 and (I think) one only in 1974. (current practice is different too.) A comfortably convenient viewpoint might well be that the air pollution features I have been talking about are really only of marginal concern in these special periods. Of course I can give you no guarantee for the future: our car traffic continues to grow, the weather is fickle—Melbourne recently had an unusual 11 day stagnation period. It is however certain that the basic air-chemistry here gives no built-in immunity, for that you must turn to town planners, controls, politicians, and perhaps the electric car.

Ozone levels in Perth were first "measured" almost a century ago. Towards the end of 1875 Sir Malcolm Fraser, then Surveyor General, had established at the Survey Office a meteorological station under his personal supervision and I think at his own expense. The data obtained are reported in the Government Gazette and starting August 18th 1876 include values for the blue colour developed on potassium iodide paper as natural air movement brought the ozone to it, not a method quantitatively validated today. Ozone was then thought to be good for you, you got it at the sunny sea-side and not in industrial towns because there the sulphur dioxide obliterated it: Perth scored well. We know something of the instrumentation: Sir James Clark's Ozone Cage, Dr. Moffat's papers and 'scale of tints', Negretti and Zambra's superior papers were in use later. Do specimens of these early ozone meters abandoned in 1900 still exist? Useful comparative information might yet be extracted from the historical Perth data?

Emissions from vegetation fires

Do we have sufficient knowledge of how Perth's air chemistry is affected by burning-off operations either far removed from the metropolitan area or by major local incidents [see postcript] such as the recurrent fires at Herdsman's Lake? The logs of Pelsaert, Vlaming and others show that dense smoke patches are not merely modern

events. The West Australian reported (Friday, December 11th, 1970) that 'A smoke haze covering the metropolitan area yesterday afternoon restricted visibility in some places to 1000 yards. Visibility was poor all day and at 5.00 p.m. it was impossible to see across the Swan River from 'Newspaper House'.' Earlier that week on a day of similar obscuration my note book (and 'The West Australian', Dec. 9th) records that *at the edge of the Darling Scarp* I could definitely smell the Los Angeles odour.

That December week the CSIRO Division of Applied Chemistry (I learned rather surprisingly two years later through the scientific literature) were studying large scale prescribed forest fires in the Manjimup area; the fire on 7/12/70 consumed 110,000 tons of fuel, and the smoke from the one on the 9th Dec. could have reached Perth the next day. Aircraft flew through the smoke plumes to measure concentrations of smoke particles and many chemical substances.

No chemist expects ozone to form in a fire, directly through combustion alone. No ozone outside the normal natural air ranges was found in these plume experiments and 50 pphm for NO_x was never reached either. In the 1971 report's words '. . . it seems most unlikely that any prescribed burn could, of itself, start a photochemical incident' (Vines *et al.* 1971).

The matter has not ended there. Why "of itself"?

Since 1971 additional information has come from new CSIRO forest burn experiments. Excess ozone has now been detected, the peak concentration being several times that of the ambient atmosphere, though (I quote) 'excessive ozone was found only in the top layer in the plume and only when the sun was shining' (i.e. photochemical).

Let me read the two concluding paragraphs of a CSIRO paper available in January last year (Evans *et al.* 1974):

"It is indeed fortunate that the excess ozone is confined to a shallow layer at the top of the plume and that the plume from controlled burning rises above 1000 metres, thereby ensuring sufficient dilution of the ozone layer to eliminate any health hazard at ground level. Nevertheless, one should keep in mind that low-level smoke may well constitute a hazard, particularly if it drifts over urban areas and merges with other urban pollutants such as nitrogen oxides, the effects of which cannot yet be predicted.

We feel that it is strange that such high ozone concentrations have not been obvious elsewhere in the world. Perhaps the indigenous eucalypt fuels used in the present work yield smokes which are particularly photosensitive." Local research is important.

Perhaps my nose was right after all on December 8th, 1970! Ozone from massive burns? Ozone from cars? Are the native plants (whose sensitivity to ozone we do not know) absolutely safe in Kings Park? The experimentalist you see must first speculate, then measure.

Power stations as ozone sources

Until recently no one expressed concern about gaseous emissions from oil-fired power stations except over sulphur dioxide. Through steadily improving technology more compact, quickly responding and more sensitive analytical chemical apparatus can now be flown through stack plumes. Just such an experiment was reported by Davis *et al.* (1974) on the plume gases from a 1000 megawatt generating station near Washington, D.C., which operates on 75% oil 25% coal. In addition to the expected chemistry near the stack, at distances around 70 kilometres down wind through sunlight action on the effluent gases there was a nett production of ozone to levels double ambient values. A surprising finding which will provoke much new experimentation and some concern where large power stations are situated to windward of urban areas.

The role of a university

What should be the University's role in further atmospheric studies in Perth? It was Joseph Conrad who authoritatively described Cape Leeuwin as 'one of the three great Capes in the World'. Far to its west, north and south we have available a vast portion of the water surface of the world. Much of Perth's air comes to us over those oceans with—by world standards—remarkably little air-borne pollution from the few ships and the infrequent aircraft. Perth then is well sited for background studies of numerous naturally occuring chemicals in the uncontaminated atmosphere. Let me cite two examples only. Some splendid studies on gaseous iodine (not sodium iodide, the salt) have recently been done at the University of Hawaii (Moyers *et al.* 1971). A southern hemispherean replication would be a proper task. Secondly, if speaking to you three years ago I would have been urging studies on the rising levels of carbon dioxide. Again the deficiency that such studies had only been done in the northern hemisphere (predominantly) is now being corrected by CSIRO's program of Base Line Atmospheric Carbon Dioxide Monitoring on high altitude commercial flights between Christchurch, New Zealand, through Perth to Mauritius (Pearman & Garratt 1973, 1975). Welcome as this development is to me, it does point up the question of whether the University can organise, staff and finance environmental programs on more than a very minor scale unless there is a firm commitment from senior policy makers, perhaps even a national science policy.

Consider—sketchily—the time scale within which an Honours student in one year or a Ph.D candidate in three must face his problem. Lectures, associated study, three or more seminars weekly, laboratory teaching, all create a fragmented week within which to cope with the experimental problem and its literature, the apparatus and its problems, and for the Ph.D candidate—getting publishable work. For the regular staff member to deviate from his established research means serious inroads into his private time—a fact University wives will verify. Add that the air is variable daily, weekly, sea-

sonaly, so that many observations are needed—a problem shared with biologists and farmers. Despite these very real constraints the University can act in exploratory roles of value to the Public Health Department and the Environmental Protection Department and this I wish to illustrate briefly with the two examples of lead, and "Freon" tracing.

Lead emission from cars

There is world wide interest in the urban distribution of lead-containing particulates emitted from the exhaust pipes of cars. Certainly humans near highways inhale lead from the air though the public health significance of this is controversial. Mr. L. Boujos as an Honours student in Physical and Inorganic Chemistry obtained local information on lead levels which supplemented the rather meagre public information available elsewhere in Australia (Bottomley & Boujos 1975).

The Causeway across Heirisson Island carries some 75,000 vehicles per day. In the 200 yard length of roadway on the Island roughly two pounds weight of lead is emitted daily through petrol combustion. The finely divided lead salts are brought to the ground to various extents and at various distances depending on the prevailing wind and weather conditions, that reaching the ground or plant surfaces is subject to weathering and leaching.

Sampling was undertaken to determine the average lead concentration in the top two centimetres of soil at various lateral distances from the edges of the roadway. The absolute values are somewhat lower than for some other Australian measurements and are considerably below extreme values for heavily urbanised areas in other countries. Whether simple intercomparison is legitimate or not is a matter itself requiring very close study.

The lead is of course not uniformly distributed in depth: there is a markedly raised concentration in the upper few centimetres of soil both near to and remote from the roadway. The immediate surface is richer still in lead, a fact of considerable importance for surface living and feeding animals. The shells of a common snail *(Pheba pisana)* at 50 metres from the roadway were five times higher in lead than comparison samples taken at Swanbourne Beach and at Rottnest Island. These snails are eaten by mice, themselves food for hawks.

The levels observed at Heirisson Island certainly do not account for all the lead emitted in past years. Some perhaps is broadcast very widely, some may be carried deep into the soil during the winter rains. Nor do we have any details of the lead run-off from the roadway into the storm drainage system, the river and the ocean. We have kept the recovered lead from Heirisson Island and Dr. Trendall urges an isotopic analysis.

An interesting experiment would be to follow the arrival rate of lead at newly created surfaces: we are doing this on artificial soil at the University, but what about the accumulation in artificial lakes near the Narrows and Hamilton interchanges—both bird sanctuaries in effect. Possible lead insults to the flora and fauna should be examined further if Heirisson Island is to become a zoological reserve (Quarles *et al.* 1974; National Academy of Sciences 1972).

Let me now deflect your interest temporarily to lead contamination in a very distant part of the world, age-dated Greenland glacier ice (Murozumi *et al.* 1969). There is evidence for regional or hemispheric pollution consequences of the boom in extraction, processing, and utilisation of lead as the Industrial Revolution encompasses Europe, and further lead deposition is thought to be due to the general adoption of lead antiknock compounds combined with the expansionary phase of car traffic.

The Perth metropolitan area doesn't have convenient local glaciers, but can we think of a comparable test here? Perhaps dateable sediments in the Swan Estuary? Another possibility is a chemical examination of the annual growth rings of trees growing during the last fifty years alongside busy highways in Perth. Dr. Wycherley has provided me with samples from Kings Park, but what I really covet (I confess) is one of the Norfolk Island pines alongside Stirling Highway at Christ Church, Claremont.

Tracing of gas emission

By the early seventies a small number of Freon tracing experiments in the Northern Hemisphere had provided information on ground level concentrations of emissions from large scale powerstations as follows. Several kilograms of a Freon refrigerant gas are released up the working stack, and are diluted and dispersed just as the normal gases are under the prevailing weather. On the ground at distances up to 20 kilometres many air samples are taken in plastic bags for later laboratory analysis. This method is practicable only because as little as 10^{-12} gram of Freon in 1 cm^3 of air is detectable by gas-liquid chromatography. (On a mass per volume basis, we could detect one needle in 100 large haystacks). This extreme sensitivity is needed to study other industrial emission problems.

In Western Australia this system has been applied to determine ground level concentrations in the Coogee Air Pollution Study (Anon. 1974). It is worth a few moments delay to trace the origins of this local experiment, the first we believe in Australia, possibly in the southern hemisphere. The University Department of Organic Chemistry has owned a g.l.c. with e.c.d. (to use the jargon) for some years, invariably fully deployed but in very different directions. Perceiving the method's potentiality I wrote in mid 1973 to Dr. O'Brien suggesting that Dr. Cattell (then Western Mining Corporation Fellow) might develop the local instrumentation appropriately. The Department of Environmental Protection with personnel assistance from the armed services and from school children arranged the logisitics of release, collection, and analysis on a day determined by the Common-

wealth Bureau of Meteorology. Remove any one of these links or the associated financial support and no data can be secured. Cooperation is important.

Such information is manifestly important to planning large scale industry within the metropolitan area or further afield and to practical verification of theoretical and simplified models of pollutant dispersion. Diverse additional applications come to mind easily. The emissions of one particular chimney can be distinguished from another emitting the same pollutant. Car emissions could be traced across the city suburbs after release from say a single car crossing the Narrows bridge. The movement of air into and from individual buildings can be followed in time and in amount. Information on persistent and troublesome odours can be obtained. My own home is frequently invaded by a smell similar to 'iodoform' arriving on gentle S. or S.E. winds in the evening. "Freon" releases from conjectured sources (decomposing lakes vegetation is one theory) could help disentangle the problem. The extreme sensitivity of the g.l.c. method might permit positive chemical identification of the offending chemical.

State Government funds, I am very glad to report, have been made available to the Department of Conservation and the Environment for an additional chromatograph housed at the University with priority use on further tracing experiments of these types.

I give one more academic example: industrial and domestic use of simple chlorinated hydrocarbons had resulted in the Northern Hemispherean air being burdened with escape material (Murray *et al.* 1973; McConnell *et al.* 1975; Wilkneiss *et al.* 1975). Comparable measurements using the chromatograph on Metropolitan air, for Indian Ocean air and at the Giles Weather Station would make an attractive Honours project and a useful contribution to world environmental information.

Funding of relevant university research

Recently the Organisation for Economic Cooperation and Development (1974) reviewed scientific and technological activity in Australia. The report states that '. . . much more could be achieved if industries, State agencies, and especially CSIRO would engage the Universities more in research work' and in urging that the Universities need more staff especially to develop their research capacities to fulfil the needs of society, notes that there cannot be a strict prerogative for so called academic research work. If the report's viewpoint becomes accepted Federal Government policy then the Universities must meet those suggestions by the creation of numerous purely research positions from Post Doctoral Fellows through to fulltime and permanent senior research appointments, which at present within Australia are virtually nonexistent and in striking contrast to the position in centres of excellence elsewhere in the world.

For almost an hour you have been patiently absorbing my suggestion that atmospheric chemistry is a field to which those recommendations might properly be applied at the tertiary educational level. Studies in the atmospheric environment may however extend from very advanced research levels of physical and mathematical sciences downwards to observations and experience by John Citizen's children, this is a superbly interdisciplinary subject which should I believe be part of everyone's education.

Whatever your assessment is, please bear in mind that in 'three score years and ten' most of us will breathe some five hundred tons of air, and what it contains.

Postscript.—Professor R. T. Prider kindly drew my attention at the close of the Address to the fire at Spectacles Swamp, Mandogalup, April 1939, having badly affected Perth residential suburbs with its smoke. The Annual Report of the Mines Department, Western Australia, for 1939 (p. 148) refers to 'choking fumes . . . plainly and objectionably noticeable even in Perth 20 miles away'.

The 'West Australian', April 28th 1939, p. 24, describes 1000 acres alight for about three weeks and includes a photograph of soil damage. Two days previously a letter headed 'Mandogalup Peat' and signed R.V.R. recalls its author's prophesy in 1914 when swamp drainage was undertaken.

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